Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP)

TEST REPORT #2

System Drop-in Test of L-40, L-41a and N-40b in Ice Machines

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This report has been made available to the public as part of the author company's participation in the AHRI's Low-GWP AREP.

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List of Tested Refrigerants' Compositions (Mass%)

L-40	R-32/R-152a/R-1234yf/R-1234ze(E) (40/10/20/30)
L-41a	R-32/R-1234yf/R-1234ze(E) (73/15/12)
N-40b	R-32/R-125/R-134a/R-1234yf (25/25/20/30)

AHRI Low-GWP AREP Report.

From Manitowoc Ice Inc.

Written by: Chuck Schlosser

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Purpose: To support the AHRI Low-GWP AREP program, and to test and compare several proposed Low GWP refrigerants that might have potential for usage in ice machine applications.

Test Refrigerants:

Honeywell L-40, was compared to R-404A.
Honeywell N-40b, was compared to R-404A.
National Refrigerants 50% R32+50% R134a, was to be compared to R-404A, but samples of the refrigerant were never received.
Honeywell L-41a, was compared to R-410A.

Application: Ice machines are a medium temperature refrigeration application. Evaporator temperatures pull down to between +10 and 0 ºF during freeze cycles. During the harvest cycle the evaporator is warmed to between 40 ºF and 55 ºF typically. We typically freeze and harvest 3-5 batches of ice per hour depending on conditions.

Test Equipment: Two test machines were selected to use in comparing the refrigerants. The first test machine was a Manitowoc model IY1404A-261. This unit is a self contained air-cooled unit, rated for indoor duty. The unit is typically used in larger full service restaurants, larger nightclubs and bars, along with institutional applications. The operating window for this machine is +40 ºF to +110 ºF ambient. This unit uses a hot gas harvest system. The unit is manufactured with a Bristol model R92J343ABCA compressor.

The second test machine was a Manitowoc model IB1094YC-161, connected to a model ICVD1095-261 condensing unit using an RC36, (35 feet), line set. This unit has the ice making head section located indoors, and a remote condensing unit located outside, typically on the roof. This unit was designed to fit on top of ice dispensers which are commonly used in fast food restaurants and "C' store applications. It is designed to produce a lot of ice very quietly in a customer environment. The operating window for the outdoor condensing unit is -20 ºF to +120 ºF ambient. This unit uses a cool vapor harvest system. This unit is manufactured with a Bristol model R92J253ABCA compressor.

High Glide Refrigerants: Besides the usual leak concerns associated with high glide refrigerants, we did see a lot of unusual expansion valve hunting during these tests. We do run very low superheat settings, but our valves operate with little of no hunting. Whether this was a result of the refrigerant glide of just slightly different pressures and temperatures associated with the test refrigerants, it was hard to tell. If we went forward with one of these refrigerants, the expansion valve bulb charges would need to be reviewed.

When we look close at the results, the model IY1404A-261, which uses a hot gas harvest cycle, we saw very consistent results with all refrigerants. The model IB1074YC-161, which uses a cool vapor harvest system, worked real well with N-40b, and not as good with L-40 and L41a. While the reasons for this are not full understood, one thought is the refrigerant may be separating in the receiver tank, since we pull our cool vapor off the top of the receiver for the harvest cycle. We also use an accumulator in these systems, and we pull vapor off the top of the accumulator through the "J" tube. It is possible that the refrigerant we are pumping during the harvest cycle may not be what we think it is. This theory would have to be explored in greater detail if a high glide refrigerant was selected.

Test Procedure: All testing was done in accordance with AHRI Standard 810; and ASHRAE standard 29. Tests were conducted at 90/70 ºF, (90 ºF ambient / 70 ºF water), temperatures. This is the standard AHRI rating condition, and the point used to compare the performance of the various refrigerants against each other, against baseline data, and certified data. Ice was measured in pounds of ice produced per day, and energy was measured in kilowatt hours required to produce 100 pounds of ice. In all cases, we waited for the units to become stable at the test conditions, and than recorded six test runs, and the results were averaged, and mean data was reported.

Testing was also done on the self contained IY1404A-261 at 40/50, 70/50 and 110/90, and on the IB1094YC-161 at -20/50, 70/50, and 120/90 just to see what happened to the new refrigerants when operated at the edges of the equipment's design envelope.

For the two refrigerants compared to R-404A; L-40, and N-40b, we tested both stock machines at 90/70 to verify they were typical and within AHRI tolerances.
We than removed the R-404A refrigerant, removed the compressors and drained the oil, and replaced it with new POE oil, reinstalled the compressors, replaced the expansion valves with new same size adjustable expansion valves, (Manitowoc ice machines use fixed setting non-adjustable expansion valves), and replaced the filter drier. After evacuation, the system was charged with new refrigerant. Due to the high glide with the new refrigerants, we charged with liquid refrigerant only. We started out our charge searches at about 75% of the nameplate R-404A refrigerant charge, and followed our standard charge search procedures; we worked in 2 ounce increments on the IY1404A-261; and in 8 ounce increments on the IY1094YC-161 system, (remote systems have much larger refrigerant charge sizes).

Ice machines run with very low superheat setting on their expansion valves, and we did have to adjust the valves to match the superheat settings as close as possible to the standard R-404A valve settings. Ice machines use a suction-liquid line heat exchange to get higher superheat back at the compressor. The heat exchanger was not modified for these tests. No other components were changed or modified for the testing when we compared to R-404A refrigerant. Between testing each refrigerant, we would remove the compressor, and drained the oil and replaced it with new POE oil, and replaced the filter drier, to keep cross contamination to a minimum.

The Honeywell L-41a refrigerant was compared to R-410A in the same two ice machines. Since the standard refrigerant in these two machines is R-404A, the machines had to be rebuilt with R-410A components, and retested with R-410A to get a reference point to compare L-41a against. We asked our suppliers such as Bristol, Danfoss, and Sporlan to provide equivalent R-410A components to use in our units for this test. We replaced the compressors, expansion valves, head pressure control valves, and pressure switches with equivalent R-410A parts, condenser coils remained the same. With R-410A, we used a Bristol model H82J173ABCA compressor in the IB1094YC system, and a Bristol model H82J243ABCA used in the IY1404A system. A charge search was run on both systems using R-410A refrigerant to establish a new performance baseline.

Test Results: Performance at Rating 90/70 Rating Condition

IY1404A-261 Test Unit; R-404A Comparison

Refrig.	Charge	90/70 Ice	Change	90/70 Energy	Change	Notes
R-404A	46 oz	1180#/day	----	4.88 Kwh/100#	----	AHRI Certified Rating
R-404A	46 oz	1227#/day	----	4.88 Kwh/100#	----	Baseline on Test Unit
L-40	41 oz	1231#/day	+3.2%	4.70 Kwh/100#	-3.7%	
N-40b	47 oz	1227#/day	0.0%	4.84 Kwh/100#	-0.8%	

IB1094YC-161 Test Unit; R-404A Comparison

Refrig.	Charge	90/70 Ice	Change	90/70 Energy	Change	Notes
R-404A	180 oz	910#/day	----	4.85 Kwh/100#	---	AHRI Certified Rating
R-404A	180 oz	928#/day	----	4.83 Kwh/100#	---	Baseline on Test Unit
L-40	184 oz	861#/day	-7.3%	5.32 Kwh/100#	+10.1%	
N-40b	144 oz	960#/day	+3.4%	4.67 Kwh/100#	-3.3%	

IY1404A-261 Test Unit; R-410A Comparison

Refrig.	Charge	90/70 Ice	Change	90/70 Energy	Change	Notes
R-410A	44 oz	1037#/day	---	4.26 Kwh/100#	---	Baseline on Test Unit
L-41a	38 oz	1030#/day	-0.7%	4.08 Kwh/100#	-4.3%	

IB1094YC-161 Test Unit; R-410A Comparison

Refrig.	Charge	90/70 Ice	Change	90/70 Energy	Change	Notes
R-410A	240 oz	753#/day	---	4.64 Kwh/100#	---	Baseline on Test Unit
L-41a	240 oz	679#/day	-9.9%	4.91 Kwh/100#	+5.8%	

Ice Capacity at Other Test Conditions:

IY1404A-261 Test Unit

Refrig.	40/50 F	70/50 F	110/90 F	90/70 F	Notes
R-404A	1520#/day	1540#/day	910#/day		Typical Values
R-404A				1180#/day	AHRI Certified Value
L-40	1519#/day	1481#/day	932#/day	1231#/day	
N-40b	1542#/day	1537#/day	920#/day	1227#/day	
L-41a	1278#/day	1166#/day	761#/day	1030#/day	

IB1094YC-161 Test Unit

Refrig.	-20/50 F	70/50 F	120/90 F	90/70 F	Notes
R-404A	1050#/day	1070#/day	670#/day		Typical Values
R-404A				910#/day	AHRI Certified Value
L-40	962#/day	963#/day	580#/day	861#/day	
N-40b	1063#/day	1035#/day	672#/day	960#/day	
L-41a	755#/day	675#/day	469#/day	679#/day	

Summary: The compressors we used for the R-410A / L-41a testing were different, and undersized, so results can only be compared to each other, and not to the R-404A, L-40, and N-40b results.
Over all, the Honeywell N-40b, had good capacity over the full range of operating conditions, and good energy efficiency, and it is rated an A1 refrigerant. The GWP was higher than some of the other candidates.